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Utilization of Wood Waste



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"The Utilization of Wood Waste"

By WALTER B. HARPER, M. S.

Author of "The Utilization of Wood Waste by Distillation."

"Wood Waste and Its Utilization"

By GEORGE B. FRANKFORTER

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St. Louis Lumberman

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SAINT LOUIS

MISSOURI

The Utilization of Wood Waste.

By WALTER B. HARPER, M. S.

Author "*The Utilization of Wood Waste by Distillation.*"

There has always been a large amount of waste incident to the manufacture of wood into lumber and other products.

Various suggestions have been advanced from time to time to utilize this waste. Some of these suggestions have been tried and proven successful and we find a much more complete utilization of the log than formerly. Most of the successful suggestions have been along mechanical lines and only a few successful chemical methods have been advanced. The chief of these latter are the making of paper and wood alcohol. Both of these industries are flourishing. Wood represents from a chemical view one of the largest supplies of organic matter and on this account should prove to be of great value industrially.

Some of the chemical methods tried are distillation of the wood to obtain various products; the manufacture of cellulose, grain alcohol, etc.

The main distilling processes are the steam process, the steam and destructive distillation process, the destructive distillation process and the steam distilling and solvent extracting process.

Several years ago the writer endeavored to bring before the lumbermen a detailed description of the various methods in use to utilize waste wood, with special reference to the distillation of yellow pine. A description of the above processes was given in full. A brief resume will be given here so as to give an idea of the present conditions.

The raw material for the various distillation processes is found in great quantity in the United States and to a limited extent in all parts of the world. It is divided into two classes, the hard woods and the soft woods. The hard woods of the North have formed the supply for wood alcohol making and the resinous woods of the South have furnished the supply for making wood turpentine. Quite recently the conditions are beginning to change and we find wood turpentine plants working on fir and pine in the North and wood alcohol plants working on some of the hardwoods of the South.

All shapes and sizes of wood are being used and economical combinations of raw material and fuel are being perfected. Wood alcohol plants are usually confined to branches and rather large pieces, the sawdust, etc., being used for fuel. This is due

to the fact that the majority of wood alcohol plants are located near charcoal iron furnaces which require relatively large pieces of charcoal. The turpentine plants use all kinds of wood from sawdust to fat pine stumps.

The destructive distillation process is the one chiefly used with hard wood, but with resinous woods a great variety of processes are used. As a general rule the finer the pieces of wood the quicker the distillation. But the heat cannot always be applied advantageously to fine wood, so it is generally used in the condition that experience teaches is the best under the given conditions. For the manufacture of charcoal only, the simplest and crudest form of distillation is the "charcoal pit." The workings of these are quite familiar. Sometimes a condenser is added to collect the vapors, but usually the yield is not large enough to pay for the trouble and expense.

1. The Steam Process.

The steam process consists in distilling finely divided resinous wood in a current of low pressure, low temperature steam, to remove volatile substances, such as turpentine and other oils. The wood is placed in a container, capable of withstanding considerable pressure, the container being called a retort, extractor or steaming chamber. Connected with this retort is a suitable condenser to condense the steam and vapors. Arrangements are made for introducing the wood and withdrawing it expeditiously after being steamed. Also suitable steam pipes, gauges, etc., are connected to the retort to regulate the operation. The retort is usually made of boiler steel and holds from one to ten cords. The condensing worm or tubes are usually made of copper, the outer shell being made of iron or wood. Suitable tanks are provided to receive the distillate. The operation is very simple. The valves connecting with the condenser are opened, live steam admitted and the pressure regulated by the valves so as to maintain the pressure as desired, usually from five to twenty-five pounds. The steam and vapors escape to the condenser, where they are condensed. The oil rises to the surface of the water and overflows into a receiving tank. The residual wood is removed from the retort and is used for fuel. The steaming operation requires from thirty minutes to

twelve hours, depending upon the class of wood, the process, the operator and the amount of pine oil to be extracted.

Resinous wood has been treated in this way for a long time, patents having been issued covering the principle as early as 1864.

Two classes of wood are generally used with the steam process, one being mill refuse and the other being selected light wood and stumps, containing as much resin as obtainable. Mill refuse is obtainable in large quantities at small expense, but the yield of oils is very small. The yield from light wood and stumps is much greater than from mill refuse, but the expense of gathering offsets in a large measure the difference in the yield. . .

There are two kinds of retorts in favor with operators, the vertical stationary retort and the rotating globular one. Some use a horizontally placed retort with mechanical discharging devices.

Each of the favored styles has its advantages and disadvantages and at present there seems to be difficulty in choosing between the two. The globular retort is nothing more than a globular digester the same as formerly used in making wood pulp, with an outlet at the axis leading to the condenser. The operation is the same as with vertical retorts, except that the ball rotates. With vertical retorts the steam has a tendency to form channels, although the pressure used generally overcomes this.

A great many plans have been devised to remove the wood from the retorts. In this respect the vertical retorts seem to have the advantage. Some well designed retorts discharge almost instantly after the bottom is removed.

On account of the several distinct advantages over other processes, the steam process has been highly favored by operating companies. The cost of plant equipment is relatively low. The capacity of the retort is relatively great, owing to the short time required to remove the turpentine. A further advantage lies in the fact that a very light colored oil is obtained which requires but a single distillation to make nearly water white. In practice the process does not seem to make as good a showing as it should, considering its numerous advantages. The great drawback has been the disposal of the residue. Only a small proportion of the residue is needed for fuel and the remainder accumulates. When located near a power house requiring enough fuel to dispose of this residue the process has met with marked success.

Where the yield from saw mill refuse is sufficiently large, this process can be used to great advantage, for the residue can be taken care of under the boilers or in the burner or slab pit.

There are several plants operating with vertically placed retorts and one or two with horizontally placed retorts. The vertical retorts are usually made with a large opening in the bottom for the discharge of the wood. It has been found impossible to stir the wood in the retort on account

of its packing when the steam is turned in. The arching of the wood in the retort has caused considerable trouble in discharging the retort. Wherever there has been any contracting of the retort at the lower end, the wood seems to wedge in to such an extent that considerable prodding of the mass is necessary to loosen it so that the wood will fall out. A device introduced to supplant bolted flanges at the bottom, consists of a bell-shaped bottom connected by a threaded rod to the top. A hand wheel above the retort works on the thread and the bottom is lowered and raised by its means similar to a valve. The diameter of such a contrivance is limited on account of the pressure increasing much more rapidly as the diameter increases.

One plant using horizontal retorts is working with more or less success on mill refuse. Another is working with light wood. Both use the same kind of a retort, the wood being discharged by means of a screw in the bottom.

There are two plants using the globular shaped retort, both of which are apparently successful. At one plant the wood is steamed for nearly ten hours so as to obtain not only the turpentine, but some of the pine oil as well. Pine oil is not as volatile as turpentine and it requires a very large amount of steam to bring over a small quantity of oil. The condensed water accumulates in the retort and the wood when discharged is wet and soft and does not burn well. A well designed plant using these globes ought to look well and give satisfactory results.

It has been found that when the wood is not finely divided that the oil does not distill very readily. To cut up the wood more finely than is done by a hog, shredders are being introduced into nearly all steam plants. The shredder treats the hogged wood and not only cuts it more finely but also tears apart the fibre to some extent. There is danger in getting the wood so fine that the steam will not pass through the wood. Machines can be obtained with the knives set at varying distances.

By the improvements thus introduced into the steam process, plants are being operated under far more favorable conditions than formerly. Although it would seem best to operate on mill refuse which can be obtained in large quantities at a low price, nevertheless most plants seem to be using the more resinous wood. This is due to the low yield of oils from the refuse. Also the refuse is owned by lumber companies, which fact prevents the entrance of outside capital. With knots and stumps as raw material, the steam process makes a more interesting operation.

The products made by the steam process are wood turpentine, pine oil and wood residues.

Steam and Destructive Distillation.

Although this method seems to be the best method for completely utilizing the waste from res-

inous woods, yet it seems to have been unsuccessful in practice. This cannot be said to be due to the process, for the operation appears to go on smoothly, but it has been due more to the bad location of the plants using the process. When carried on properly, this process yields almost as much turpentine as the steam process, and with as good a color when properly refined. The oil usually requires two distillations to make of the proper color. A single distillation in a column still doesn't appear to be as satisfactory as two separate distillations.

To operate the process, large pieces of wood are placed in a suitable retort, the retort heated externally to a low temperature and live steam, either superheated or not, is introduced into the retort to remove the turpentine vapors, this part of the operation being similar to the steam process. After the turpentine has been removed, the external heat is increased gradually until all volatile products have been removed. The residue is charcoal.

Destructive Process.

Destructive Distillation.

Destructive distillation is the term generally used to denote the decomposition of a substance, particularly an organic substance, by means of heat. When wood is distilled in this way a great many products are formed. As the products formed are not only volatile except charcoal, but also inflammable, it is necessary to take these facts into consideration, if these products are to be saved.

At first only the charcoal was saved, the volatile matters being allowed to escape. Later, apparatus was devised that recovered all the products.

To save the volatile matters coming from the wood, various retorts have been devised, varying within wide limits, according to the kind of wood to be distilled. The simplest form of apparatus for saving the vapors formed by destructive distillation consists of an enclosed vessel, called a retort, surrounded by a suitable furnace, to which heat can be applied by means of coal, wood, oil, gas or electricity, the vessel being supplied with a vapor pipe, connecting with some form of condenser. Some kind of tank is also needed in which to collect the condensed products. Where there is acid, the retorts are made of iron, the connecting pipes and condensing tubes of copper and the receiving tank of wood or copper-lined.

Using hard wood the products sought are charcoal, acetates and wood alcohol. The retorts used are of two distinct types, those placed horizontally in the furnace and those set vertically. Of the horizontal type there are two classes, the rectangular ovens and the cylindrical retorts. Of the vertical type there are three classes, the fixed retort, the movable retort and the fixed retort with movable cage.

Most of the retorts are made of boiler plate, three-eighths inch or more in thickness. Formerly

cast iron and clay retorts were used, but although they do not burn out as readily as wrought iron, they must be made thicker to have the same strength, and have the further disadvantage of cracking when heated.

Of the horizontal types, the ovens are the most numerous. They are rectangular in shape, flat on the bottom and slightly arched at the top. The bottom is supplied with rails. On the sides or back are one or more openings for the exit of the vapors to be condensed. The wood is loaded on steel cars holding about two and one-half cords each, and rolled into the retorts. The ovens are about six feet wide, seven feet high and of various lengths to hold two, three or four cars each. One or two coolers are used with each of these retorts, of similar shape to the retorts but of lighter material, into which the car of charcoal is withdrawn soon after the end of the distillation.

Some of the cylindrical retorts are made nine feet long by fifty inches in diameter and will hold about a cord each. These retorts are charged and emptied by hand. An iron box mounted on wheels is used to hold the hot charcoal and when full it is covered with a sheet iron cover and the edges luted with clay.

Of the vertical retorts no particular type seems to have the preference. The retorts are usually made cylindrical and hold from one-half to five cords of wood. A convenient size is about two cords. The fixed retorts remain in the brickwork and are attached to the vapor pipe of the condenser by one or two pipes, preferably one at the top and one at the bottom. The movable retorts are so arranged that they can be pulled out of the furnace when the wood is charred and allowed to cool unopened. Instead of hoisting the retort itself some types use a retort with a removable cage. Only the cage is removed and as the cage does not have to stand the direct heat of the fire, it can be made of lighter material than the retort and the removing of the cage instead of the retort saves the wear and tear of the brickwork. In addition to this, the vapor pipes are not disturbed.

The larger sizes of vertical retorts require hoisting apparatus in order to charge the wood, and there is always danger of a rope breaking, thus causing much damage. The vertical retorts are much easier to charge and are easier to clean out than the horizontal ones, particularly while hot.

Charcoal produced in closed vessels is the finest quality obtainable.

For treating resinous woods by destructive distillation, a great many modified processes are used. Although the steam process seems to offer so many advantages of operation, nevertheless when the price of turpentine falls below a certain point, the steam process plants are obliged to cease operations. A low price of turpentine affects the destructive processes also, but not in such a marked degree. Not being dependent entirely upon one

product, the destructive process has a better chance of success if favorably located. It is well understood by the trade that a trust controls the turpentine, rosin and tar trade and that it fixes prices arbitrarily. This is not the case with charcoal. If so, it is a different trust. Due to the demand for charcoal and by-products, plants using destructive processes have been able to maintain themselves for years. Of the successful plants, no two seem to use the same kind of apparatus. One uses a comparatively large retort set horizontally and heats slowly at first to remove the turpentine; this operation being followed by regular destructive distillation. One plant uses quite small retorts set horizontally, but collects all the distillate together. Another uses vertical retorts and fractionates the vapors, a process which improves the quality of the tar. One plant uses brick ovens for extracting the turpentine and brick kilns for making charcoal out of the residue left.

A process for making turpentine only, which could be followed by destructive distillation consists in pumping hot rosin directly into a retort full of wood, the rosin being kept in circulation by means of a pump. The rosin is kept hot by reheating as it circulates. The results obtained are said to be very satisfactory, the turpentine being extracted in about eight to ten hours and the yield large. There is probably a large rosin loss to be considered, particularly if the wood is not very resinous. A large plant is being built at which this process is to be used. The apparatus is very expensive. Its operation will be watched with interest.

A peculiar fact in connection with the destructive plants is that one plant finds a ready market for charcoal in the summer, one plant finds the better market in the winter, while a third finds a ready market all the year around, but at a less price than is obtained by the other two. This shows the care needed in selecting a proper location.

Extraction Processes.

The extraction processes consists in treating finely ground wood by suitable solvents to obtain valuable products such as turpentine, rosin, etc. The advantage of the extraction processes lies in the complete utilization of the raw material without outside expenses. The greatest disadvantage lies in the losses inherent in the process.

The residue from the steam process still contains the resin and part of the pine oils. An ideal process would seem to be one that would extract all the turpentine and resin from the wood and leave the fibre intact. The fibre could be used for fuel or possibly the cheaper grades of paper.

To do this several methods have been proposed based upon the solubility of resin in common solvents. Among the solvents used have been gasoline, alcohol, benzine, turpentine and the soda alkalies. Generally, the turpentine is removed first

and then the resin is extracted from the wood by the solvent action of one of the above substances. By proper treatment nearly all the resin can be quite easily extracted from the wood. The secret of success lies in two things. These are the quality of the rosin produced and the percentage of recovery of the solvent. If the solvent is not recoverable the process will not succeed. At present there is a very large solvent loss.

The use of neutral volatile solvents for extracting resin from resinous woods, both before or after the removal of the turpentine, has been known for a long time. The only question concerning their use has been in regard to the economy of the operation. As early as 1865, patents were issued in the U. S. describing the process as being well known at that time. The use of the alkaline solvents is more recent although the possibility of using them for this purpose has also been known for a long time.

On account of the low price of turpentine and rosin in the early days of the industry none of the processes for treating resinous woods could have been profitable. Several patents have been issued in recent years covering the same ground as the older patents, yet all claiming originality. On account of the higher price of the finished products than formerly obtained, the extraction processes have been attended with better chances of success. The use of cups and gutters in the old process of tapping trees has caused a falling off in the production of low grade rosins and a consequent enhancement of price. This has been of great benefit to those companies using extraction processes and has caused a marked success in their operation.

The cheapest volatile solvent available seems to be gasoline or possibly petroleum naphtha; caustic soda and carbonate of soda have also been used. Other solvents act equally well and some even more quickly than gasoline, but being expensive the recovery loss is greater than the advantages gained by quicker solvent action.

The process as carried out with gasoline is as follows: Finely divided wood is placed in a series of vessels, called retorts or extractors. These extractors are connected by means of suitable pipes and valves to a condenser and also to a solvent tank. The turpentine is removed by means of low pressure, low temperature steam in exactly the same manner that it has been extracted for years by the steam process.

After the turpentine has been removed, the wood is dried by a current of hot air or otherwise and the solvent pumped in. The solvent passes from one extractor to another until it has taken up as large an amount of the resin as convenient, usually an amount equal to the percentage of resin in the wood. The solvent is heated in its passage through the different extractors by means of a steam coil placed in the bottom of the extractor. The gasoline or other solvent dissolves the resins and

the remaining turpentine and pine oil and the solution thus obtained is filtered or clarified. It is then distilled to remove the gasoline and turpentine, then further distilled to remove the pine oil. Generally the heating is done by steam, but it could be done by direct heat. When the resin is of the proper consistency it is allowed to flow out of the still. When the resin has been extracted from the wood in any particular extractor, this one is cut out from the series. The wood in it is then steamed to recover the adhering solvent.

Using alkali, the process would be similar as far as the extracting were concerned. The recovery of the resin and soda from the solution is a quite different operation from the recovery of gasoline. Soda will not distill in steam, so it is either necessary to boil down the resin and soda to a solid condition (called resin soap) or else to neutralize the soda with an acid. By this latter method the resin is set free, and it is collected and boiled down to the proper consistency.

The extraction process leaves as a residue the woody fibre. This is used for fuel. Much more fuel is needed than is required by the straight steam process for turpentine only.

This extraction process seems to be a very good utilization of resinous woods and is particularly adapted to knots and stumps. It appears to be better than the steam process alone, in that it works up all its products within itself and leaves but little residue.

The main disadvantages lie in the production of unsuitable products and loss of solvent. So far the rosin produced has not been up to the standard as to color, odor and consistency. The color has been much improved of late. It may be possible to remove the odor and the product can be made more firm by boiling a little longer. It is to be hoped that the manufacturers of stump rosin will be careful not to put inferior goods in the market. Wood turpentine is just beginning to overcome the bad reputation it attained in the early days of the industry when inferior grades were marketed.

Condensers.

Nearly all the processes heretofore mentioned require condensers. A description of these different kinds can be found elsewhere. The most popular kinds seem to be the worm condenser and the tubular. For neatness of appearance, cheapness and economy of space the tubular are to be preferred. Using condensing water under pressure the worm condenser would be preferred.

The tubular condenser consists of a number of small copper tubes expanded into two tube plates one on each end. These tubes are set vertically. Above them and connected tightly to the tube plate is the vapor dome, while below is the liquor pan to catch the condensed vapors. The vapors enter the vapor dome, pass through the tubes, which are surrounded by water, and the condensed liquid falls

into the liquid pan and then out through a pipe to a receiving tank. The condenser is usually set in a steel tank containing circulating water. The water enters at the bottom and overflows hot at the top, the flow being in an opposite direction to the flow of vapors.

The worm condenser is simply a pipe larger in diameter at the vapor inlet than at the other. This pipe is arranged in coils, one coil above the other and the whole set in a tank. The tail pipe projects through the tank. The tank contains circulating water. The coils being usually made of large diameter, require a large tank. This makes it necessary to use more water. When the water is under pressure the top of the tank is closed over.

Gas Making.

It is possible to make gas from wood and less than a century ago cities on continental Europe were lighted with wood gas. Coal gas soon supplanted wood gas as the former was much cheaper and the quality much better.

However, there are many sections in this country where wood gas could still be produced at profit. This is particularly true in those localities where saw mills are in operation. Water gas can be made from wood as well as producer gas. In the former articles on utilizing wood waste a description was given of a wood gas producer which had been used for some time in France. This producer is of the form known as the Suction Type and is based on the down-draft principle. Within the last few years a modification of this producer has been designed and some of the objectionable features overcome. As this form of a producer can utilize sawdust and shavings to advantage a brief description is advisable.

The producer or generator is built like an ordinary coal gas producer and consists of a shell of iron lined with brick. The grates are of fire brick and all gas pipes leading directly to and from the generator are lined with fire brick. Generally two generators are used together and are interconnected. Above the grates is placed a layer of coke which is not consumed. The generators are connected with a boiler or condenser which cools the gases. There are also a wet and dry scrubber for the gases, a gas holder and an exhauster.

To operate the producer with wood, coke is placed in a small layer on top of the grates and a wood fire kindled above. The gases formed at first are not collected but allowed to escape into the open air. After the fire is thoroughly kindled the gas is delivered into the holder. As the wood contains water no steam is used, except occasionally to stir up the fire. The air comes in at the top and also the fresh wood. Charcoal is at the bottom and the products of distillation from the wood pass through the glowing charcoal and coke and are thus split up into permanent gases. Very little oxygen reaches the coke at the bottom with-

out being previously consumed. Wood makes a small quantity of fine ash and this is carried out through the coke into the condensers and scrubbers. The air is drawn in at the top and gases and steam are drawn out at the bottom by means of the exhauster, into the boiler or condenser. The water is here removed if there be any not decomposed and the gas passes on to the scrubbers. Here the gas is washed by spraying with cold water and passing over trays of coke. The gas then passes through the exhauster and forced through the dry scrubber or to the outside air. After passing through the dry scrubber it goes to the gas holder.

To make water gas, a modified process is used. The wood in one generator is heated very strongly until the charcoal produced is brought to such a temperature that it will readily decompose steam. The gas formed is allowed to escape into the air. The other generator is cut off from the boiler by means of a valve and the openings at the top of both generators closed. The two boilers are then interconnected. Steam is admitted to the bottom of the one not connected with the boiler. The steam rises through this generator and is drawn into the top of the other generator and passes down through the bed of hot charcoal where it is decomposed into hydrogen and carbon monoxide. As no air is admitted with the steam, strong water gas is formed.

As such a generating system can be used with slabs and mill refuse, it would seem that it might be possible to utilize such refuse to advantage as a source of power and heat and even light. Three to five pounds of wood in such an apparatus is equivalent to a pound of coal. One sawmill of ordinary capacity would supply enough material to furnish several hundred thousand cubic feet per day.

Ethyl Alcohol.

Another method of utilizing waste material from saw mill operations is that of making ethyl or grain alcohol.

That cellulose (which comprises a large part of woody fibre) can be converted into a fermentable sugar by the influence of dilute mineral acids, has been known for a long time. The solution of this sugar being fermented, ethyl alcohol is produced and it can be recovered by distillation.

The writer knows of no successful method of obtaining alcohol from sawdust on a large scale. A few attempts have been made but they have all been unsuccessful. Some new plants have started up quite recently, but the prospects for their success are not favorable. There are two causes for failure, both chemical. To carry out any of the proposed processes expeditiously, it is necessary to treat the wood under pressure with a mineral acid. So far no container has been found that will stand the action of the acid. When iron is used a sulph-carbonate of iron is formed which decreases the yield of alcohol.

There are two general processes used for the conversion of sawdust into sugar. One process uses sulphuric acid and the other sulphurous. To the writer's knowledge four plants have been built in the U. S. within recent years. One plant using the sulphurous acid gas process, made a great many attempts to operate successfully, but was obliged to close down. One plant built on a smaller scale is now operating with so-called success, but as this is being directly operated by the promoters of the process, reliable information cannot be obtained. Another plant operating in the West is claiming greater than the theoretical yields and one in the South not making any claims at all is obtaining only about one-half the expected yield.

The writer has visited one of the largest of these alcohol plants and is not favorably impressed with the prospect of success under present conditions. The loss due to plant depreciation must be very great. The danger of explosions of a digester is very serious and the pipes are sure to be destroyed by the acid sooner or later.

In a former article a description of the sulphurous acid process was given at length. The treatment with sulphuric acid is very similar, the chief difference being that with sulphuric acid there is no recovery of the acid. At the time of writing the previous article a large plant was in operation in the South, using the sulphurous acid process. One reason for failure was given that the digesters being lined with lead could not be made to withstand the acid. There was also some trouble disposing of the residues. There is a possibility of overcoming most of the troubles of these processes and if alcohol can be produced at from 5 to 10c per gallon without considering plant depreciation it is to be hoped that a way will be found soon to do this.

A description of a plant using the sulphuric acid process is given below.

The plant was erected of a size to treat 100 cords of sawdust per day with the expectation of producing 1,200,000 proof gallons per year. The sawdust and hogged wood is obtained from a saw mill near by. The hogged wood is chipped so as to get it as fine as sawdust if possible. The sawdust is carried to a bin directly over the digesters. The digesters are globular in shape and made of steel. They are made exactly like wood pulp digesters and are about ten to eleven feet in diameter. They are lined in the inside with acid-proof brick, the joints being made with silica cement. The plant has been running but a short time and this lining has been satisfactory so far. There are four of these digesters in operation. The sawdust is dropped in through the manhole and at the same time a dilute solution of sulphuric acid added. After replacing the manhead, the digester is rotated, steam is introduced into the mass and the pressure raised until the temperature reaches a little over 300 degrees Fahrenheit. That temperature is main-

tained for about ten minutes when the steam is shut off and the pressure blown off into the air. Using pine wood this blow off should contain turpentine. The digester is stopped rotating long enough to remove the manhead, then allowed to rotate again. The sawdust is thus discharged into a bin below the digesters, the acid filtering through and flowing to the neutralizing vats. The heated sawdust is then taken from the bottom bin by means of a belt conveyor and discharged into a regular beet-sugar diffusion battery. Here the sugar is washed out and the solution sent to the neutralizing vat. The solution is neutralized with lime, the gypsum formed not separating to any great extent. The clear liquid is taken from the vats and pumped to the fermenting vats. Here it is mixed with a certain amount of grain to insure proper fermentation and the yeast added. The alcoholic liquor formed is distilled in a continuous still up to proof and the proof spirit redistilled in a column still to about 92 per cent alcohol. The alcohol is considered to be the very best but a slight green tinge was discernible.

The following from the Consular Report of Consul General Frank H. Mason, Paris, covers the process as used in France. "The company which manufactures alcohol from sawdust operates what is known as the Ciassen process, which, instead of treating the sawdust with a liquid sulphate solution, exposes it in rotary drums to the action of sulphurous acid gas, whereby alcohol is produced, which may be used for a much greater range of purposes than ordinary wood alcohol.

When worked under the best conditions this process yields from 10 to 11 liters of alcohol per 220 pounds of sawdust treated.

Difficulty With the Apparatus.

The director of the company informs me that they have encountered serious mechanical difficulty with their apparatus, as a consequence of which their works have shut down for repairs, viz.: The large rotary drums in which the sawdust is exposed to the sulphurous acid gas are made of iron and must be lined with lead to resist the action of the acid, but they have found it impossible by the usual methods, to have this lining made so tight and perfect that it will stand for any length of time without developing cracks and imperfections which permit the gas to penetrate through and attack the iron of the shell. This not only risks spoiling the drum, but generates a sulfo-carbonate of iron, which mixes with the material and reduces generation of alcohol to 8 or 9 liters per 220 pounds of sawdust.

During the last summer the company learned of the Schoop process of covering iron with a coating of lead, zinc, or other metal by blowing the latter in a molten vaporized condition against the iron. They found that their tanks and cylinders could be successfully lined with lead by this process, and their plant was shut down for that pur-

pose, but they expected to start up again soon after January 1, 1911.

Sales of Alcohol and By-Products Success of Process.

The present condition of the company is therefore one of expectation. They claim to have demonstrated fully the practical value of their process, but by reason of trouble with the linings of the apparatus they have not achieved the industrial success which they anticipated. They sold during the two months prior to closing down for repairs, 15,235 gallons of alcohol, and derived as their principal by-products methylene in a very pure state and acetic acid in the form of pyrolignite of lime."

Cellulose.

The manufacture of pure cellulose from woody fibre is not attended with much success. Usually the raw material for this purpose is cotton. However, paper or wood pulp in impure form of cellulose is made in enormous quantities from wood.

The wood pulp industry although well established when using spruce wood and other soft woods is not so successful with refuse wood as the raw material. Experiments are being conducted at Wasau, Wisconsin, by the Forest Service to discover methods for the utilization of the waste from lumbering operations in that State as a source of raw material for the pulp industry. The success of these experiments have not been definitely announced.

A venture in the South for making straw board from yellow pine refuse has not been completed on account of lack of funds to finish the construction of the plant.

Another plant in the South has been working up selected refuse into paper for years. Until recently it has been considered largely as an experiment, but the capacity of the plant has been increased greatly and it is now on a manufacturing basis. The cost of the plant is estimated as being close to a million dollars and is expected to be a very profitable investment. The capacity of the plant is rated at 75,000 pounds of pulp and 60,000 pounds of paper daily.

The process used is the Soda Process. It consists in boiling the wood with a 12 degree Baume caustic solution at about 100 pounds pressure. An upright digester is used and from the top of the digester a pipe leads off to a condenser where the turpentine is recovered. The quantity and quality of the turpentine coming off has proved to be a good guide as to when the wood has been thoroughly "cooked." The caustic is washed out of the pulp as nearly as possible in the usual manner and evaporated down in vacuum effects until of the right consistency to burn. The thick liquor is burned in a rotary incinerator, the heat making steam in the connecting boiler. The black ash is collected and washed in settling tanks, then the solution sent to the causticizing tanks to be

treated with lime thus recovering a large part of the caustic.

The washed pulp is then sent through the paper making machinery and comes out as a finished product of good quality. To avoid bleaching coloring matter is added to the pulp and colored papers produced.

Paper making from yellow pine is not as economical a process as it might seem owing to the difficulties encountered in bleaching economically. It is claimed that the Sulphate Process is quite well adapted to this class of wood and that the fibre produced bleaches readily.

Wood Coloring.

Attempts have been made to utilize inferior woods such as gum and the like by a process of coloring.

One process in actual operation consists in treating small logs in suitable machinery so that the ends are chamfered, then passing the log to another machine consisting of two funnel-shaped iron cups connected to a pump. The chamfered ends of the log fit in the funnel-shaped cups, the cups are squeezed together and a solution of coloring matter pumped through from one end to the other, the excess solution being reused. Sometimes a suitable wax is mixed with the solution and both pumped hot through the wood. The effect is surprising. A wood is produced that needs no special varnishing. If it is scratched, a little polishing brings out the wax and color. Wood thus treated is being used in considerable quantities for furniture. A multi-color machine is in use which makes a variegated color extending through the log. Sometimes it is necessary to dry the log, so to do this a current of hot, compressed air is driven through the log before adding the coloring solution. This apparatus treats the log in a horizontal position.

An attempt is being made with more or less success to do the same kind of coloring in the ordinary creosoting cylinders. Instead of using creosote to fill the pores of the wood, a solution of a coloring matter is substituted.

Still another method of coloring wood is the one in use of treating the standing tree with a solution of coloring matter. It is claimed that this process is giving better success than either of the other two methods.

Whether a uniformity of distribution of the coloring matter in the pores can be obtained to such an extent as to satisfy a large number of consumers there seems to be some doubt. Probably a multicolor machine might give satisfaction in this respect.

Creosoted Wood Block Paving.

It is not necessary to consider the advantages and disadvantages of creosoted wood block paving. Much information concerning the use of wood blocks for paving can be easily obtained.

There is a possibility of utilizing sawdust by

means of destructive distillation retorts, to obtain a wood creosote at a reasonable expense. A combination of a wood block creosoting outfit and a sawdust distilling outfit might make a happy combination which could be used to advantage by saw mill owners. Some experimenting would be necessary in order obtain a suitable apparatus for distilling sawdust satisfactorily.

Food Products.

It has been often jokingly remarked that some of our breakfast foods are made of sawdust. That such may be a true statement in the future is barely possible.

In connection with the manufacture of grain alcohol from wood, it has been stated that sawdust can be converted into sugar by the influence of dilute mineral acids. This sugar is fermentable and digestible. Another sugar formed at the same time is not fermentable but may be digestible. Being mixed with acid it would not be very palatable.

However, it has been proposed to treat sawdust with hydrochloric acid gas and thus to convert the sawdust into digestible products. The hope is to recover the gaseous acid by means of heat and thus reuse it.

Probably, the acid still adhering to the wood should be neutralized with soda, to produce common salt in sufficient quantity to make the treated wood palatable!

In regard to wood distillation proper the general status of the industry is unfavorable. In the North the wood alcohol sale has been severely crippled by the use of denatured alcohol. In the South the high prices for spirits of turpentine stimulated the trade for a brief period, but the recent slump in prices has made the turpentine business very dull.

There have been so many failures of wood distilling plants in the South that some definite cause must be assigned for this.

The writer has visited many such plants within the last six months and the consensus of opinion as expressed has been that the average wood obtainable, which is suitable for distillation processes does not contain enough oil and other products to carry on the operation successfully. True it is that some of the wood obtainable give enormous yields, (fifty-one gallons of refined turpentine being reported to four thousand pounds of wood) and on the strength of this promoters have been able to demonstrate to the uninitiated the wonderful results to be expected from the operation of a wood distilling plant. The quality of the wood obtainable in quantity determines the success or failure of these enterprises.

Unless definite tests are made on average wood gathered over large area, the yield of valuable products will be so much smaller than what is stated by promoters, that any investment in this direction will result in failure.

Wood Waste and Its Utilization.

By GEORGE B. FRANKFORTER.

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The United States is the most wasteful nation in the world: wasteful in living, wasteful in manufacturing, and wasteful in conserving its natural resources. This prodigality of the nation's wealth has been largely due to extravagant methods of manufacture. A quarter of a century ago, when economical methods were not considered essential to industrial life, practically every industry in the whole country was the very synonym of waste and extravagance. Our unparalleled wealth of natural resources, together with high tariff walls, made it unnecessary to manufacturers to utilize by-products in order to earn large dividends or to compete with other nations.

It is a remarkable fact that while these great storehouses of natural products had become necessary to the world's industrial progress, in only a few cases were the raw materials converted into marketable products at home. On the contrary, they were sent abroad to be worked up by highly technical institutions, and returned at many times the value of the crude products. In the early years of our industrial development, the very idea of utilizing what was then called industrial waste, seems to have been distasteful to the whole nation. Our manufacturers did not understand the new by-product movement which had given the European nations industrial supremacy; neither were they willing even to try to understand it. They saw only the great treasures stored up in our mines, our forests or in our great fertile plains. They would not see the small but no less important things which belonged to the new by-product movement. It was doubtless this unfortunate condition which kept the highly technical chemical industries from the rapid growth which would have followed under more favorable conditions. With everything at our doors for which a nation could ask, and with a demand for the products which can only be made from by-product waste, it seems strange to the chemist of today that our industries should have remained so long in this undeveloped condition. The only logical conclusion which may be drawn is that the American people were either not desirous or not capable of developing the industries to that degree which has made the German Empire what it is today.

It should be stated here, in justice to the chemists of the present, and out of genuine respect for

the pioneers of the last generation, that the undeveloped condition of our chemical industries can in no way be attributed to them. As a matter of fact, chemists have, throughout the whole of our industrial life, occupied a peculiar position. Their work has been largely a labor of love, a love for the science and a love for mankind; at any rate, they have received little else for their labor. They have repeatedly sounded warning notes of waste and extravagance to the industries and incidentally urged them to employ the new economical methods of manufacture if the United States were to be considered in the industrial race of the future. This frantic appeal to the people of the country to stop the wanton destruction of our national resources has, until recently, been entirely ignored. The classical work of the chemists of the East, with their campaign of industrial education, is having a most wholesome influence upon the eastern industries. The work in the Middle West, North, West and South is likewise having a salutary effect upon the manufacturers, for they are beginning to see that it is better to save at the spigot than it is to save at the bung. On the whole, there is hope of a great industrial revival such as that which has made Germany the greatest of the industrial world-powers.

It is at least encouraging to the chemist at the present time to find that industrial conditions are changing for the better. What changes one can safely predict in the near future may be inferred from the great industrial chemical wave which swept over Germany during the latter half of the 19th century. That magical change which enabled the German people to spring from the fourth to the very first of the industrial world-powers, was due to the wonderful development of their chemical industries and to the amazing methods of conserving their natural resources. Germs of this same reconstruction period, I think, may be found in our own conservation movement. Waste in manufacturing is no longer entirely overlooked by the industries as it was a quarter of a century or even a decade ago.

Notwithstanding the marked improvement in our present industrial condition, it is still evident that industrial conservation will be ignored by the majority of manufacturers unless they have convincing proof that conservative methods mean greater

profits and less expense. Their one thought, perhaps a logical one, seems to be of profits. Unfortunately, they have not recognized the fundamental fact that an industry is of vital importance as a national asset only when it conserves the nation's resources and produces the greatest possible returns for the least possible consumption of natural products.

The Wood Industry.

That a revolution of our industrial world has been going on is evident from a study of any one of our great industries. We have already reached the reconstruction period, as is evident from a glance at the greatest of our conservation problems—the wood industry. Fifteen years ago it was impossible to interest lumbermen in any of the wood by-product industries. The real reason seems to have been that the lumbermen found it unnecessary to build up highly technical by-product plants in order to earn large dividends, either in home or foreign markets.

Of the great wastage problems before the American people today, wood refuse probably stands first. Few realize the awful waste in the processes used at the present time by the lumbering industries. The industrial chemist is astonished to find that millions of cords of good wood are being burned, either on the ground, where it took hundreds of years to grow, or in huge burners built at the mills for the express purpose of destruction. He is more than astonished to find that laws have been enacted in some of the great timber states compelling the lumbermen to burn all waste wood left on the ground after the logs have been removed. These laws were ostensibly passed for the prevention of forest fires, but doubtless without fully realizing the actual value of the millions of cords of waste.

The term timber has a distinctly local significance. In its broadest meaning, and especially in the great lumbering states of the North, West and South, it represents the forest capable of being converted into lumber. On the Pacific coast, the term is applied only to those mighty forests which have been growing for a thousand years. On the western plains, any growth of trees, scrub, oak, elm, ash or birch, is called timber. The term is little used in the Middle States, since the depletion of the virgin forests. I have used the word in its broadest sense, as representing trees of all kinds, large or small, which may be converted into marketable products.

Concerning the study of the timber industry of the middle, northern and western states, the writer has had exceptional opportunities. His early years were spent in close touch with lumbering industry of the middle states. Later, on the great plains of the west, he learned the true value of timber. On coming to one of the greatest timber states some seventeen years ago, he realized more fully than ever the frightful waste in the conversion of timber into lumber. With this almost

criminal waste of over half of the great forests vividly in mind, he decided to devote some time, at least, to the wood by-product industry. In these early years the task proved so herculean that grave doubts often arose as to whether waste wood from the logging and milling industries could ever be utilized. The work was all the more discouraging on account of the indifference of the lumbermen. They were too busy with the industry as it then existed to give any attention to waste problems. Furthermore, they sincerely believed that wood waste was unavoidable and that its utilization was an absolute impossibility. During these early years, about the only hope of the chemist was in making the lumbermen realize that better and more economical methods were possible and impressing upon them the important fact that wood waste, with proper encouragement, would become the greatest by-product industry in the world.

The important questions which naturally occur to the industrial chemist in these days of conservation are: first, to what extent are the great industries actually wasting our natural resources, and second, can our present industrial methods be so improved as to materially reduce this waste? It requires but a glance to convince one that the waste attending logging and milling industries is the most colossal ever recorded in the history of manufacture. Here, then, is such an opportunity for conservation methods as occurs in no other industry in the country.

It is impossible to even estimate the waste which followed the lumbering industries a single decade ago. A general idea may be obtained of the waste at present, however, by glancing at any of the large mills. The best that these model mills can do today, by most rigid economy and by using all the modern improvements known to the industry, is to save a scant 40 per cent of the total weight of wood in lumber, lath and shingles. Fifteen years ago the average was probably not over 30 per cent.

The Logging Industry.

That the waste wood problem might be more thoroughly investigated, the whole timber industry was studied. Logging, now considered as an entirely separate industry, naturally came first. It was studied in the Middle West and later on the western coast. If the chemist is surprised at the waste produced by the mills, he is simply appalled at the waste which follows the logging industry. It is impossible to give a clear idea of the amount of wood destroyed through the present methods of logging, without details regarding machinery, quality of timber and methods used in different localities, all of which are too technical for this short paper.

The Proportion of Lumber to Waste.

Early in these investigations it was found that no one, even the lumbermen themselves, knew

what proportion of the tree was converted into lumber and what proportion was waste. That at least approximate results might be obtained, several determinations were made, weighing the whole tree so far as possible and the amount of lumber obtained.

The following is an average of three trees:

Total weight of trees.....	Lbs. 6,600
Total weight of lumber.....	2,300
Waste	4,300

Per cent of lumber, 34.84; per cent of waste, 65.16.

Stumps, tops, slabs and sawdust are included under waste, but not leaves, twigs, small limbs and small roots. No attempt was made to determine the relative weights of lumber and waste in the large trees of the West, on account of the magnitude of the undertaking, of which one may get an idea from the actual size of the tree. For instance, a Douglas fir stump from the Pacific coast was blasted out and shipped to Minneapolis for experimental purposes. The large stump made nine large dray loads of wood when cut up. To have determined the exact proportion of lumber and waste in this tree would have been a difficult task. Expert lumbermen are inclined to think that the percentage of lumber in these large trees will be somewhat greater than that given above. This will doubtless depend upon conditions. In the case of resinous fir, the trees are frequently cut from ten to fifteen feet above the ground in order to eliminate the resin which exists largely in the roots and the lower part of the trunk. The waste in such cases will exceed the above results.

Waste Wood as Slabs and Sawdust.

While waste wood in the form of stumps and tops represents a large porportion of the total weight of the tree, probably not far from the total weight of the lumber, the actual loss produced in sawing the logs is considerable. From 5 to 15 per cent of the logs goes into slabs. A part of these slabs is cut into shingles and lath. There is still, however, considerable loss from this source, although less than from the sawdust. The old-fashioned circular saw of thirty years ago cut as high as three-eighths of an inch and the old blade saw even more than that. The waste in sawdust, using a three-eighths inch saw, would probably amount to one-third of the weight of the whole log. The cut has been reduced nearly one-half by the introduction of band, bang and band-gang saws. The waste, however, is still great, not far from 20 per cent when inch lumber is sawed.

In order to put the waste wood problem in such form as to give a general idea of the amount of wood destroyed annually by the lumber industries, I have chosen a single locality and a single lumbering plant, calculating results from actual lumbering data. The great mills of the C. A. Smith Timber Company, at Marshfield, Oregon, have been selected because they are recognized by lumber

experts throughout the country as the most economical mills in existence. These mills are using every known device which will save a single foot of lumber or a single day's labor. They are among the largest in the world and have been repeatedly called "models of economy." A very brief description of some of the economical machinery will, I am sure, be of some interest to the industrial chemist. The mills are located, as are practically all of the great mills of the country, so that the logs may be transported a part of the way, at least, by water. The trees are felled, cut into as great lengths as possible, and brought down the mountains by means of cables and donkey engines to the logging railroads. They are loaded on specially constructed cars and hauled to the nearest streams of water, where they are thrown in and floated to the mills in booms. At the mill they are cut to proper lengths and split into forms called slips or flitches, by great band saws. These saws are capable of handling logs 80 feet in length and 8 feet in diameter. The slips then go directly to the band-gang or tandem saws. The band-gang saws are entirely new inventions. They are not only more rapid than the old circular and gang saws but also far more economical, wasting approximately 30 per cent less wood than the old circular saw. From the band-gang saws the lumber is finished by going through the edgers and trimmers.

Of special interest is the lath machinery, consisting of horizontal band saws, which are also an entirely new invention. These saws work automatically and cut 25,000 lath every ten hours. The great importance of this new machinery is its comparative economy. Probably 20 per cent more lath may be cut from the waste than by the old form.

The Destruction of Waste Wood.

In the early development of the lumbering industries, one of the serious problems which confronted the lumbermen was the disposal of the mill waste, including the sawdust, slabs and bark. In the older mills of fifty years ago, this was hauled away and dumped. A little of it, of course, was used in the mill for fuel, but it has always been regarded by the lumbermen as a nuisance, largely on account of the danger from fire. When the great mills of the Middle West were built, the quantity of sawdust, slabs and bark was so great that the question of its disposal became a serious one. For very good reasons, lumbermen were not permitted to dump any of the waste into rivers or lakes. Some simple means of disposal became absolutely necessary. The so-called waste burner, which was finally devised, has become a regular fixture in the modern lumbering mill. It consists of a vertical cylinder, the size of which depends upon the amount of waste to be burned. The largest is more than 100 feet high, from 40 to 50 feet in diameter, and so constructed that the

wood is carried part way to the top and dropped down on the fire below. With a strong draught, the wood burns very rapidly. One may get some idea of the amount of wood burned from the fact that a single large burner will destroy from 800 to 1000 cords in ten hours. Twenty years ago, when the lumbering industry was at its height in Minnesota, there were destroyed at Minneapolis and the neighboring mills 1,500 to 2,000 cords of waste daily, or enough to have supplied the farmers of the whole state of Minnesota with fuel.

These figures include wastage only from the trees actually felled and transported to the mills for lumber. They do not include the million of young trees which are destroyed, either by the large falling trees or by the fires which follow in the wake of the loggers. The Bureau of Forestry has called attention to the fact that this destruction of young timber, although minimized by the lumbermen, is in reality, more vital to the nation than the actual lumber waste, because it seriously menaces the lumber industry of the future generations.

The Annual Wood Wastage.

It seldom occurs, even to the chemist, that wood is by far the most abundant organic substance in the world. The weight of wood or vegetable fiber, as compared with animal matter, is probably not far from a hundred thousand to one. Wood, then, is one of the nation's greatest assets, and its conservation and preservation means the conservation and preservation of the nation's wealth.

The Marshfield mills will again give one a general idea of the waste which accompanies the lumbering industry. This plant saws, on an average, 100,000,000 feet of lumber a year. The average weight of 1000 feet (board measure) of lumber is about one and one-half tons. The annual output of this mill, then, is approximately 150,000 tons of lumber. On the basis of 60 per cent of waste, the enormous quantity of 225,000 tons of wood are burned, either on the ground where hundreds of years were required for its growth, or in engines of destruction at the mills. A very conservative estimate of the standing timber in this locality, which will eventually be cut by these mills, is 30,000,000 feet. Assuming that this timber will all be cut on the above basis, there will be the astounding equivalent of 45,000,000,000 feet of waste which, converted into weight, will amount to the colossal sum of 67,500,000 tons. These figures are enormous, but they seem small when compared with the lumber output during the last decade or even the yearly output. There were cut in 1907, according to the Bureau of Forestry, 40,256,154,000 feet of lumber. On the above basis, there were in that year over 100,000,000,000 feet and over 150,000,000 tons of wastage.

Wood Analyses.

At the time this work was begun there were no analyses of either Norway pine or Douglas fir.

The first work on these species was a study of the physical properties of the wood, followed by analyses, including the distillation products, fiber, the resin and the terpenes. The physical properties of the wood showed a striking variation, even in wood from the same tree. It was not uncommon to find the extreme wood limits of specific gravity in the same tree. A series of determinations on different parts of the same tree gave the following:

	Fir.	Norway.
Specific gravity of very lean wood.....	0.6074	0.6025
Specific gravity of medium wood.....	0.6711	0.5432
Specific gravity of resinous wood.....	0.8225	0.7384
Specific gravity of very resinous wood.....	0.9456	0.9322
Specific gravity of green roots, very resinous	0.9746	0.9721

The above averages of five different determinations indicate that the two species are quite similar. There was a difference, however, in distribution of the resinous matter. The Norway pine was quite uniform, the stumps and the roots being nearly always resinous. The fir, on the contrary, was extremely variable. It was not uncommon to find parts of fir trees containing as high as 50 per cent of oleoresin, while other parts of the same tree contained as low as 3 per cent.

The first resin and terpene analyses were made for the purpose of determining the relative amounts of resin and terpenes in the various samples of wood, and further for the purpose of studying the physical and chemical properties of the resin and the terpenes themselves. These determinations were made by extracting the wood in large modified forms of Soxhlet extractors, using the various organic solvents. An average of some twenty analyses gave the following:

	Lean wood.	Resinous wood.	Aver. wood.
Pct. of oleoresin in Norway pine.....	6	43	14
Pct. of oleoresin in Douglas fir.....	4	46	16

The amount of oleoresin in the average wood will be seen to be considerably less than the mean of the lean and the rich wood. This was found to be due to the fact that the greater portion of the wood was lean. These results were all obtained from stumps. Analyses of the trunks themselves gave considerably lower results. Parts of the tree near wind-shakes, however, gave even higher results than the stumps. A single analysis of a resinous wind-shaken tree from the Puget Sound district gave 52.5 per cent of oleoresin. The oleoresin was finally subjected to steam distillation and the amounts of resin and terpenes determined:

	Fir.	Norway.
Per cent of resin in oleoresin from.....	78	78
Per cent of terpenes.....	22	22

These results are an average of many determinations and indicate that the proportions of resin and terpenes are practically constant in oleoresin fresh from the tree. The terpenes decrease slowly on exposure to the air. An analysis of wood from a stump twenty years after the tree had been cut showed 42.4 per cent of resinous matter, 21 per cent of which was turpentine. The

only part of this stump which seemed to have changed was the surface; here the resinous matter had become hard and impervious to both air and water.

The Terpenes.

The terms terpenes and turpentine have been used synonymously for the reason that the turpentine from the northern species is complex, containing several high boiling terpenes. Common turpentine has been so closely associated with so many branches of industrial art that, were it taken away, the loss would be irreparable unless some good substitute could be found. At the present time nearly all the turpentine is obtained from the forests of the South. The old method of boxing sooner or later kills the tree. In the early history of the industry three or four years was the average life of the boxed tree. Much better results are now obtained by the new methods of turpentine orcharding. A few years ago the destruction of the forests of the South was so rapid that the United States government became alarmed lest the turpentine industry should be completely destroyed.

At the present time the northern and western states play a very small part in the resin and turpentine production of the country, but, as has already been stated, these northern species contain large quantities of both resin and turpentine. Owing to the peculiarities of the species, however, their recovery becomes strictly a problem of by-product chemistry. In fact, resin and turpentine are abundant enough in both the Norway pine and the Douglas fir to make them an important factor in the resin and turpentine output of the country if economical methods for their recovery were used.

Using again the lumbering plant above mentioned, some idea may be obtained of the amount of resin and turpentine wasted by the lumbering industries of the West. Probably one-fifth of the fir and Norway pine waste wood is rich enough in oleoresin to make its recovery profitable, even by the old process of destructive distillation. While the average of oleoresin in the northern species of pine can only be approximated, over one hundred analyses of wood of all kinds and degrees of resinousness indicates that one-fifth of the fir wood waste from the Puget Sound district contains 20 per cent of oleoresin. On the above basis there are 45,000 tons of rich resinous wood, containing 9,000 tons of oleoresin, of which 1,980 tons are turpentine, destroyed annually by the above-mentioned mills. This does not include the resinous matter in the other four-fifths of the wastage. If the standing timber in the locality be again taken at 30,000,000,000 feet, the wastage would at the present rate of lumbering amount to 67,500,000 tons. One-fifth of this waste, or 13,500,000 tons, is sufficiently rich in resinous matter to warrant the use of any good method for its

recovery. Assuming that this amount will average even 10 per cent of oleoresin, there would be the enormous sum of 1,350,000 tons of resinous matter, of which 22 per cent, or 297,000 tons, are turpentine. Translated into common terms, it reaches the colossal sum of over 80,000,000 gallons. Again, assuming that the annual consumption of turpentine is 21,000,000 gallons, the above amount would supply the whole world for nearly four years.

Present Methods of Utilizing Waste Woods.

There are numerous methods of utilizing waste wood at the present time, but the more important may be grouped under the following heads:

1. Fuel, yielding heat and power.
2. Destructive Distillation, yielding charcoal, and distillates, as tar, wood alcohol and pyroligneous acid.
3. Extraction, yielding resinous matter, turpentine, wood pulp.

Fuel.

The present generation is truly one of conservation, for men are beginning to estimate everything from the energetic point of view. Coal, for instance, is bought to-day largely on the basis of the amount of heat energy it will produce. Waste wood becomes significant even when considered from the standpoint of heat energy for the amount of energy wrapped in our forests is incalculable. An idea of the loss of energy in waste wood may be obtained by determining the amount of heat energy liberated when wood burns. The heat of combustion of average fir wood is about 7,800 British thermal units per pound of wood. This heat energy may be converted into eigs or into horse power, a more familiar term; or better, it may be converted into the equivalent of bituminous coal. Good coal yields about 13,000 British thermal units per pound of coal. One ton of wood will then be equivalent to six-tenths of a ton of coal. If the total annual waste above mentioned be translated into the equivalent of bituminous coal it will amount to the enormous sum of 90,000,000 tons.

Destructive Distillation.

Destructive distillation of wood has been used for centuries. Primarily the object was to obtain charcoal, although in some cases distillation of hard wood was carried on for the purpose of obtaining the distillates. Destructive distillation in retorts on a large scale is a distinctly modern process and is one of the most important by-product industries. The distillation of coal by the closed retort process yields by-products of greater value than the coke itself.

At the time these experiments were begun the only means of utilizing waste wood of any kind in this country, so far as I am aware, was by de-

structive distillation. It was soon found that the distillation of pine wood was quite a different process from the distillation of hard wood. In the distillation of hard wood it makes comparatively little difference how the heat is applied to the retort so long as the temperature is raised sufficiently high to drive off all the distillates. The distillation of pine wood, on the contrary, is different. The nature and the yield of tar, and more especially terpens, were found to be largely dependent upon the manner of heating the wood.

In order that definite results might be obtained concerning the manner of heating the wood, experiments were made in a small retort so arranged that the retort could be heated to a red heat in a few minutes. The amount of turpentine, tar and acids was greatly reduced by this rapid heating. A sample of wood containing 30 per cent of oleoresin, 22 per cent of which was turpentine, was suddenly heated to a bright red heat, yielded less than half of the total weight of resin in tar and only a quarter of the total amount of turpentine. The yield in the same sample of wood was nearly doubled by slow and cautious heating.

Having found that the yield of by-products is largely dependent upon the manner of heating, experiments were next made with different shaped retorts, in order that the best and most efficient form might be determined. The one which gave best results was so constructed that the temperature of the wood could be gradually raised to the distilling point. This was accomplished by using a long inclined cordate tube retort, the lower end of which could be heated to a red heat, while the upper end could be kept moderately cool. The retort was arranged so that the wood was admitted at the upper or cool end, gradually passing downward by gravity and by a mechanical device until it reached the lower or red-hot end of the retore. By this means the least possible amounts of both resin and turpentine were decomposed. The retort was also constructed so that the oleoresin could escape from the retort without being distilled. To accomplish this openings were made in the cordate lobes of the upper end of the retort, in order that the oleoresin when removed from the wood, by "trying out," might pass through these bottom openings instead of passing through the ones in the top of the retort by vaporization. It was found that a portion of oleoresin could be removed by this process with but slight indications of decomposition. The amount of tar was increased, its quality improved and nearly all of the turpentine was recovered.

In order to obtain as accurate data as possible waste pine wood from the forests and mills of the North and West was subjected to destructive distillation and the distillates as well as the charcoal determined. The following table is a comparison of the results obtained by distilling the three common species:

	Norway pine. Lbs.	So. pine. Lbs.	Douglas fir. Lbs.
Weight of wood taken.....	100	100	100
Charcoal	24	22	24
Gaseous products	25	26	24
Tar and terpenes	14	14	14
Pyroigneous acid, including water	37	38	38

From these results it will appear that the three species of pine are very nearly alike. Each sample was what would be called resinous wood. The samples of the northern and western wood were largely taken from the stumps, although some were from the resinous part of the tree. The southern samples were confined to the trunks of several trees brought from the turpentine forests of Florida. The yield of turpentine in each case was somewhat less than the total amount existing in the wood or obtained by either steam distillation or by extraction. The loss was found to be due to the decomposition of the oleoresin by heat. This was especially noticeable when the distillation took place rapidly. For instance, wood containing 5 per cent of turpentine only yielded 2 per cent by rapid distillation.

While the retort described gave very satisfactory results so far as by-products were concerned, the chief difficulty lay in the market value of the products. The tar, which has a real value abroad and even in the South, was found to be practically worthless in the North and West, despite the determined efforts to utilize it in the paint, wood preservation and other industries. Most of the distillation plants of the North and West actually burn the tar and throw away the pyroigneous acid. As pine wood yields only a trace of alcohol the only marketable products left are the turpentine and charcoal. The latter, however, has little value, hence the whole process of pine wood distillation in the North resolves itself into the recovery of the turpentine. As a considerable quantity of the turpentine is lost, even by the most improved processes of distillation, other methods of utilizing the waste wood seemed absolutely necessary. The above experiments are of some interest, however, because they were the first made on the wood of the northern and western species of pine and incidentally show that the yield of gaseous as well as other products is dependent largely upon the method of distillation.

Realizing, after years of labor in perfecting apparatus for the economical distillation of pine wood, that some other process than distillation must be found if the waste wood of the North and the West is to be converted into products of any economical value, the whole plan was changed from distillation to extraction. The reason for the change is evident from a comparison of the products obtained by the two processes. As has already been stated, the only real marketable product obtained by distillation is turpentine. By the extraction process practically all of the wood is converted into commercial products, namely, resin, turpentine and wood fiber, any one of which

is worth more at least in the North than all of the distillation products.

At the time this work was begun there was little hope of an extraction process which could be used for the recovery of both the resin and the terpenes. The cost, with the losses which necessarily follow a process of this kind, excluded the use of all of the common solvents. The first experiments made along this line were with steam. It was found that the terpenes could be easily removed from the wood by superheated steam. That definite results might be obtained, retorts were built so that steam could be passed through them under pressure. The wood was chipped into small pieces, placed in these retorts and distilled with superheated steam. The terpenes were quickly and quantitatively removed. The difficulty with this process was that the resin still remained in the wood and some method for its recovery was necessary before the process could be considered satisfactory. The only solution, therefore, was in the use of the common solvents.

As the steam process required two separate operations, experiments were made, excluding the steam and using the solvents direct. All of the common solvents were tried, among them petroleum ether, benzene, ether and carbon disulphide. It is worthy of note that in the early stages of this work the cost of benzene entirely excluded its use. Later, however, the supply of crude benzene from the coke industry made it more satisfactory than its sister solvent, petroleum ether.

After trying various forms of apparatus, one depending upon common extraction principles was adopted as giving best results. The apparatus was so constructed that several extraction chambers, arranged somewhat after a beet sugar diffusion battery, were connected with a large steam-heated boiler containing the solvent. The arrangement was such that by heating the boiler the vapors of the solvent could be forced through any one of the extraction chambers containing the wood, where the vapors were condensed and returned to the boiler laden with the oleoresin. After the extraction was completed the last traces of the solvent were removed by forcing through the wood, air, steam and, finally, hot alkali, for the conversion of the wood into pulp. By this treatment all of the resinous matter was removed, the solvent recovered with very slight loss and the wood was converted into pulp.

The terpenes of both the Norway pine and the Douglas fir have been already described.¹ The properties of the terpenes obtained by extraction were identical in every respect with those obtained by boxing. The resin from the Norway pine has likewise been described.² The resin from the Douglas fir, under examination at present, resembles the resin of the southern pine. It is composed chiefly of abietic acid with an acid

of unknown composition and a small quantity of unsaponifiable matter.

Paper from Waste Wood.

The paper industry has become one of the greatest and most important parts of our commercial fabric. But a few years ago nearly all of the paper was made from cotton and linen rags, hemp, flax and jute. Very little paper was made from wood pulp. At the time this work was begun there was not a single pulp mill in the whole northwest. They are now counted by the score. Spruce wood is chiefly used in this locality for the reason that it is readily reduced and requires little bleaching. Spruce, however, is becoming scarce. The price has nearly doubled within the last five years. At the present rate of consumption all of the spruce wood in Minnesota, Michigan and Wisconsin will have been used up within the next decade and other sources must be found. White pine, cottonwood, basswood, hemlock, birch and even soft maple give perfectly satisfactory results. As a matter of fact, any wood belonging to the pine family may be used. Even the stumps, roots and branches of the Norway pine and Douglas fir make an excellent grade of pulp when properly treated.

In studying wood waste with the idea of converting the fiber into pulp, various methods for the manufacture of paper were tried. The sulphite process, the one universally used in the northwest, was thoroughly tested. It proved unsatisfactory on account of the fact that even a very small amount of insoluble resinous matter turns black in sulphite solution. The soda process, with certain modifications, was found to work satisfactorily and especially with extracted wood. A number of pulp determinations were made, using wood from different parts of the tree. An average of several determinations gave the following:

Wood pulp in	Per cent.
Norway pine stmps.....	27
Douglas fir stumps.....	24
Fir sawdust	22
Southern pine	23

The highest yield of 43 per cent of fiber was obtained from lean fir wood, thoroughly seasoned, while the lowest, of 16 per cent, was obtained from green resinous fir. It was found by actual test that the fiber from this waste wood was equal to the best obtained from spruce, by either the sulphite or the soda process. Recent experiments show that even sawdust, by careful treatment, yields a fiber of good enough quality to make any of the common paper.

If waste wood is again considered from the standpoint of paper, its economic value is greatly magnified. Some idea of the total waste from the paper point of view may be obtained by again using the annual waste from the above-mentioned mills. Of the 225,000 tons of waste wood, at least one-half can be converted into pulp at a minimum

¹J. Am. Chem. Soc., 28, 1467.

²Ibid., 31, 561.

cost. From actual experiments this waste averages 22 per cent of pulp. The annual amount of pulp wasted in this one locality, then, is little less than 25,000 tons. When one finally considers the total waste throughout the North, West and South the waste wood problem from the paper side alone looms up as one of the most vital problems with which the American people have to deal.

In conclusion I will state that the technical and

minor details have been purposely omitted. The chief object of this general resume of work which I have been carrying on for a number of years is to interest my colleagues in the great wood problem. If waste wood is to be converted into its most valuable by-products, industrial chemists must join in the work. There are hundreds of uses to which this waste may be put when once this great problem is exhaustively studied.

Complimentary Letters on the St. Louis Lumberman

CONTINENTAL LUMBER CO.

Houston, Tex.



We consider it the best advocate of the yellow pine industry in existence.

FORDYCE LUMBER CO.

Fordyce, Ark.



Our ad. in St. Louis Lumberman has given us perfect satisfaction. We desire to express our appreciation of the work it has done in the interests of lumber manufacturers.

MISSOURI LUMBER & MINING CO.

Grandin, Mo.



Your paper has certainly kept pace with the times, and is in the front rank of progressive journalism.

J. F. WILDER

Epps, Miss.



The South, and particularly the yellow pine manufacturers, always have a warm spot in their hearts for The St. Louis Lumberman. It deserves the success it has attained.

BEAUMONT LUMBER CO.

Beaumont, Tex.



The instructive articles published from time to time have been very acceptable reading, and covering such a wide range of subjects holds something to interest every man.

BOWMAN-HICKS LUMBER CO.

Kansas City, Mo.



There are, of course, other lumber journals, but the "Lumberman," as a live, up-to-date trade journal, is "equalled by few and surpassed by none;" and as a consistent friend and champion of yellow pine interests it is in a class by itself.

TEN-MILE LUMBER CO.

Ten Mile, Miss.



I take this opportunity as one of your friends to thank you for your always standing up for the interest of the yellow pine saw mills.

YELLOW PINE MANUFACTURERS

ON THE
ST. LOUIS LUMBERMAN AS
AN ADVERTISING MEDIUM.

LONG-BELL LUMBER CO.

Kansas City, Mo.



I have watched with a great deal of interest the growth of your paper.

I believe that your publication has done more for the yellow pine interests than any other in existence.

LUTCHER-MOORE LUMBER CO.

Orange, Texas



The St. Louis Lumberman is not only one of the best papers in the country, but we firmly believe it wider and more closely read by those most interested than any other paper.

LOCK, MOORE & CO., Ltd.,

West Lake, La.



The business we have been able to trace as the direct result of our advertising is very satisfactory, and our Purchasing Department find it almost indispensable as a reference book.

WM. BUCHANAN.

St. Louis, Mo.



I consider the St. Louis Lumberman one of the best papers of its kind in the country. It is of such value that as you well know, I have instructed you to send it to all my travelling representatives.

FROST-JOHNSON LUMBER CO.

St. Louis, Mo.



Aside from its value as an advertising medium and newspaper, the able and successful work it has accomplished in its field places it not only in the front rank of lumber publications, but in my opinion, of American trade journalism taken collectively.

CENTRAL COAL & COKE CO.

Kansas City, Mo.



We have been doing business with your paper for fourteen years. The St. Louis Lumberman is the only real yellow pine paper in the business.

Do You Know

That St. Louis is the largest consuming and distributing market for Southern lumber in this or any other country?

Do You Know

That, on account of this fact, *The Lumberman's* regular reviews of the Southern Lumber Field are more valuable and more sought for than any other?

Do You Know

That *The Lumberman* contains more Southern correspondence and advertising than any other journal?

Do You Know

That *The Lumberman* is the recognized organ of the Southern Lumber Field, and is the Largest Lumber Paper in the World?

Do You Know

That St. Louis is the largest distributing market in the Mississippi Valley for saw mill, woodworking, power and other machinery and supplies for the Trans-Mississippi West, and the larger and more rapidly developing portion of the South?

If You Know

All this, the chances are that you're in a business in which *The St. Louis Lumberman* is, or should be, of especial interest to you!

The ST. LOUIS LUMBERMAN

LUMBERMEN'S BUILDING

8th and Pine Streets

SAINT LOUIS

MISSOURI

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You Want to Sell or Buy

SECOND-HAND WOOD-WORKING
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THING PERTAINING THERETO....

If... You Want A Man

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USE THE

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